TRENDS FOR DIGITAL AERIAL MAPPING CAMERAS

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ABSTRACT:

More and more analogue cameras are replaced by digital aerial cameras, which is a major change for the industry in various aspects. Organizations tendering out aerial photo flight projects will need information about new sensors on the market and their characteristics. There are big differences in accuracy, image quality and data format. Camera buyers have the challenge to select the right sensor which will address their business model the best. Independent and objective sensor comparisons are rare. Features are not easy to compare, some are hidden and last but not least in most cases the acquisition of a digital aerial camera is a major investment with no comparison to the old analogue world. It is also a big opportunity for new companies to step into the photo flight business. The vendors have also the challenge to address the demands of a market which changes rapidly every year. There are new dynamics which are difficult to predict. Development of a good digital sensor is expensive and requires long development cycles. This paper deals with each of these aspects and will provide some guidelines for future decisions for mapping organizations and buyers. It will also explain Intergraph's view on the future of the digital sensors and will give an outlook into its plans for new developments. This paper will also explain more critical aspects for tender documents and will include a generic example for digital photo flight specification.

1. INTRODUCTION

With the introduction of digital aerial cameras, significantly more vendors have come into the market, whereas for the film cameras, only three large format camera vendors existed. For business decisions, either to purchase a new camera system or to contract aerial image acquisition, it is important to recall some of the main camera parameters and to understand the differences between the old traditional analogue cameras and the new state of the art digital cameras. The latter are divided into several categories: large format cameras (e.g. the Intergraph DMC), medium format cameras and small format cameras. Not all digital cameras have multispectral capabilities. Some of them can collect image data with only 3 colour channels. The high end systems have 4 colour channels. This rich variety in digital camera technology makes it even more difficult for the buyer to select the right camera system.

2. ANALOGUE CAMERA PARAMETERS

All large format film cameras have a standard square sensor format, 9” x 9” film or 230 mm x 230 mm. Calculation for mission planning is based on this square sensor format. The most common focal lengths are 150 mm (wide angle camera) and 300 mm (normal angle camera). There are other focal lengths available as well. Because of the square sensor format, the field of view is the same in both the flight direction and across the flight line. The optical system of a film camera has a very high resolution. Good cameras have more than 100 line pairs/mm optical resolution. This is required to meet the specs of high resolution film, although for film based aerial colour images, only 40 to 50 line pairs/mm resolution can be achieved on average. This is influenced by the film type, atmospheric effects like dust and haze, and film development.

The mission parameters for the photo flight with film based cameras are determined by the photo scale required for the project.

The photo scale for analogue cameras is calculated with the following formula:

$$\text{photo scale} = h_g / c_k \qquad (1)$$

Where h_g = flying height above ground
c_k = focal length

In most cases the analogue image is scanned. Very common scan resolutions are 12.5 micron to 21 micron. By digitizing the analogue film, a ground sampling distance (GSD) is introduced for each pixel.

The GSD for a scanned aerial image can be calculated using the following formula:

$$\text{GSD} = \text{photo scale x scanning resolution} \qquad (2)$$

If aerial images are acquired with film cameras and the image data will be processed in a digital photogrammetric environment, it is essential to plan in advance for the GSD required for the final image product.

3. DIGITAL CAMERA PARAMETERS

For digital cameras there is no standard sensor format. The market is divided into large format cameras (as the Intergraph

DMC), medium format cameras and small format cameras. Most of these cameras have a rectangular image format, where the larger dimension is in the across-flight direction to minimize the number of required flight lines for photo flights. The sensor size is defined in pixels (e.g. for the Intergraph DMC 13824 x 7680 pixels). There is a wide range of focal lengths from around 62 mm up to 120 mm. Because of the rectangular sensor format, the field of view is different in the flight direction and across the flight line. For digital cameras, the pixel size of the CCD must be considered. Depending on the CCD manufacturer, there are CCDs with pixel size varying from 7 micron to 12 micron. For each digital camera, the combination of focal length and pixel size determines its operation profile. Mission parameters for photo flights with digital cameras are determined by the required ground sampling distance (GSD).

The GSD for digital cameras is calculated with the following formula:

$$GSD = h_g / c_k \times \text{CCD pixel size} \qquad (3)$$

Where h_g = flying height above ground
c_k = focal length

For the Intergraph Digital Mapping Camera DMC, the GSD can be calculated by dividing the flying height above ground by a factor of 10,000. The DMC has 120 mm focal length and 12 micron CCD pixel size.

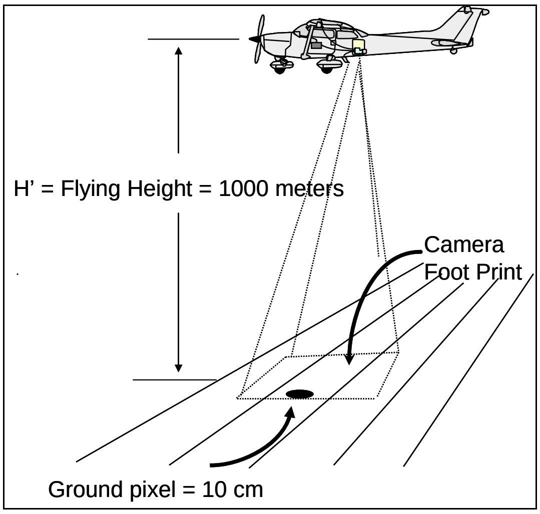

Figure 1. calculation of GSD for the Intergraph DMC

4. CHALLENGES FOR PHOTO FLIGHT CONTRACTING AUTHORITIES

Mapping companies and contracting authorities have to adapt specifications for photo flights to the new digital technology. Currently available tender documentation is focused on film based analog cameras. Some of the parameters can not directly be transferred from the analog world into digital, e.g. resolving power of the optical system. To give one example, for film cameras very often photo flight tenders require an optical resolving power of 100 line pairs per millimetre or more. This value can not be used for digital sensors, because it is an essential requirement for sensor design to adapt the optical resolving power with the pixel size of the used CCD. If the resolving power of the optical system is much too high, image artefacts can be introduced (image aliasing). A digital camera using a 12 micron CCD pixel size requires an optical design with approx 50 line pairs/mm optical resolution.

Digital cameras with small pixel size can not produce images at higher resolution than cameras with a larger pixel size. The ground resolution is determined by the combination of flying height, focal length and CCD pixel size as explained with formula 3. This means that the specification of a CCD pixel size in a photo flight tender makes no sense.

When the project includes both RGB and Color IR data it is important to define if the data can be acquired during two separate missions, during one flight but with two cameras or during one flight with a four channel camera system.

5. IMPORTANT PARAMETER FOR PHOTO FLIGHT TENDER SPECIFICATION

To specify tenders for photo flights with digital cameras some new parameters are introduced. First and foremost the required ground resolution (GSD) has to be specified. This has a major impact on flying cost and later on also data processing cost. If the GSD is specified too high (high GSD means small pixel size on the ground) more flight lines will be required and the amount of data per area will increase. It is recommended to specify both a target GSD and a minimum GSD to allow some flexibility because of terrain variation.

6. HARD CHOICE FOR SENSOR SYSTEM BUYERS

In contrast to analog sensors, where only 3 large format film cameras had been around, there are many digital cameras available today. There are a variety of different technologies and design approaches and also there is a wide range of purchase prices. The buyer has to find his way through the jungle of technology. Depending on the business model there are adequate sensors available on the market. Sensors are divided into categories like frame sensors, line scanner, large format cameras, mid format cameras, small format cameras, metric cameras, etc. Each sensor has unique technical features, like electronic forward motion compensation or micro Bayer colour filter. These features have a huge impact on performance. It is important to understand what technical feature will be required for a particular application. A sensor used for stereo feature compilation requires different technical characteristics than a camera used for rapid Ortho production.
For digital cameras forward motion compensation is implemented using TDI Time Delay Integration.

Electronic forward motion compensation can only be implemented for digital cameras based on frame sensors. For line sensors this technology can not be applied. Also for digital cameras using CCDs with Bayer micro colour filters, electronic forward motion compensation can not be applied.

The efficiency of a digital camera can not always be directly derived from its sensor size; it is a more complex system where other elements and parameters are involved. The ground coverage for one image of a frame sensor based camera can easily be calculated by multiplying the number of pixels in X and Y with the GSD using formula 3. Using the target GSD for a specific project, the required flying height above ground can be calculated also using formula 3. The US National Agriculture Imaging Project NAIP requires 1 m GSD. To achieve this pixel size on the ground, a very high flying height is required. There may be air traffic control restrictions for certain flying heights, e.g. to avoid collision with commercial air traffic. This may force service providers to fly lower with certain camera models. The achieved GSD will then be smaller and as a consequence the footprint for one image is smaller and thus the productivity of the camera is reduced. A smaller GSD will result in more flight lines and more images.

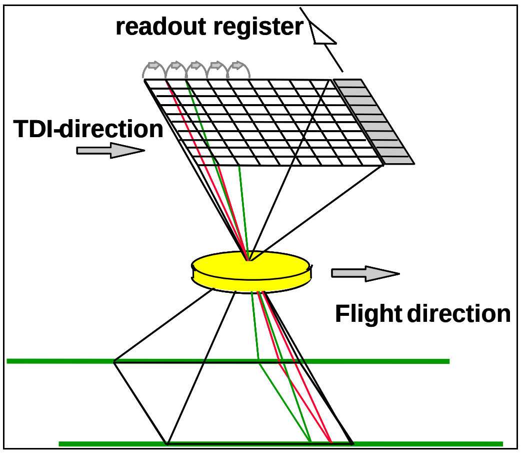

Figure 2. digital forward motion compensation

It is important to calculate in advance if the selected digital camera type will fit with the business model of the company. In the following, the Intergraph DMC will be compared with another camera model.

Camera	Focal length	CCD pixels size	Sensor size in X	Sensor size in Y
DMC	120 mm	12 micron	13824 pixel	7640 pixel
Model A	100 mm	7,2 micron	14000 pixel	9000 pixel

Table 1. camera parameter comparison

Even though camera model A has a large CCD size (more pixels in X and Y) the ground coverage achieved at the same flying height is smaller. Table 2 shows the results.

Camera	Flying height	GSD	Ground coverage
DMC	30000 ft	91,4 cm	12635 m x 6982 m
Model A	30000 ft	65,8 cm	9212 m x 5922 m

Table 2. camera ground coverage comparison

As a result, the ground coverage of the DMC is approx 40% larger than the ground coverage of camera model A if both cameras are operated at the same flying height.

For service providers, flying an aerial camera in a non-pressurized aircraft will have a huge cost impact if it is necessary to fly at higher altitudes where the crew are required to wear oxygen masks. For maximum productivity the ideal combination is a camera system where large ground coverage can be achieved at maximum flying height without oxygen mask. For the western China mapping project at 1:50000 scale these are important considerations for buyers planning to invest into a digital camera system.

7. NEW SENSOR DEVELOPMENTS

Customers familiar with film cameras and who consider entering the digital world are looking for the same accuracy they had been used to for many years, plus all the advantages of digital camera systems on top, all at the price of a film camera. This is a challenge for the industry.

Development of digital aerial cameras is also a technical challenge for the vendors. Compared to old film cameras, the amount of electronic components has increased and thus the life cycle time of the product reduced. The challenge is to mitigate the risk using components with long life cycles and at the same time to develop a high performance sensor at reasonable cost. Another challenge the vendors are facing is limited influence on CCD manufacturers to tune their sensors for aerial camera application. CCD technology is dominated and influenced by consumer cameras which have different requirements for application.

As explained earlier in this paper, digital camera systems can be divided into 3 categories, large format, medium format and small format systems. There are 3 vendors for large format cameras, Leica ADS40, Vexcel UltraCam and Intergraph DMC. There is a variety of small format camera systems on the market, with few exceptions they are based on components developed for studio cameras, such as commercial digital backs.

There is no real high precision multispectral metric medium format camera system on the market yet. A camera system with half the footprint of a large format camera, but with the same geometric accuracy and high radiometric quality would fill this gap. Intergraph is currently looking at this idea and is evaluating all options for such a development.

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